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ORIGINAL PAPER

Comparative study of some soil properties in forested and deforested areas in Cox's Bazar and Rangamati Districts, Bangladesh

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Abstract: The study dealt with the assessment of impact of deforestation on soil through a comparative analysis of soil physicochemical properties of natural forest and deforested areas. Soil samples from three depths (top, middle and bottom) under natural forest and nearby deforested areas were collected to investigate soil properties. Forest soils show no significant change in particle size distribution. Bulk density of forested soils shows the significant differences in top and middle layers. Soil pH in top and middle soil, organic matter in top soil and available phosphorus in middle soil of the forest site are found to be significantly higher than that of the deforested soils. Forest soils also have significantly higher level of exchangeable Ca^{2+}, K^+ in top and middle soil and Mg^{2+} at all depth than those of deforested site. Exchangeable Na^+ and cation exchange capacity (CEC) are observed unchanged in both sites. The results suggest that change in soil properties was more obvious in surface and sub surface portions of both areas. The study shows that deterioration of physicochemical properties occurred due to deforestation.

Keywords: chemical characteristics; deforested soil; forest soil; physical characteristics

Introduction

Bangladesh has a total land area of 144 000 km^2, and almost 17% of the total is demarcated as forest land. However, the actual forest area is only about 871 000 ha, only about 6.69% of total land area, and the rest has been deforested (Mongabay 2000). With increasing population, the demand for wood further increases. Land is also continually being cleared in Bangladesh to provide space for settlements and agriculture, and the rate of deforestation currently significantly exceeds the rate of forest renewal. From 1990 to 2005, Bangladesh lost 1.3% of its forest cover, around 11 000 ha (Mongabay 2000). Natural forest is disappearing very rapidly and at present a high proportion (46.9%) consists of forest plantations (FAO 2001). A survey also showed that an estimated 73 000 ha of natural forests have been lost due to encroachment for aquaculture, agriculture and other land uses (Hoque et al. 1997).

Ecologically natural forests of Bangladesh fall under three main types: Evergreen and semi-evergreen forests in the hilly areas, deciduous forests in the central terrace areas, and mangrove forests in the littoral zone (FAO 2000). The hill forests are mainly situated in the districts of Chittagong, Cox's Bazar, Rangamati, Khagrachari, Bandarban and Sylhet. The total area of the hill forest is 670 000 ha, about 4.54% of total area of Bangladesh (Anonymous 1992). The hill forests are ecologically more important and constitute more than half of the forests of the country. The dominant tree species are Garjan (*Dipterocarpus spp*.), Chapalish (*Artocarpus chaplasha*), Telsur (*Hopea odorata*), Tali (*Palaquium polyanthrum*), Kamdeb (*Callophyllum polyanthum*), Urium (*Mangifera sylvatica*), Jarul (*Legarstromia speciosa*), Civit (*Swintonia floribunda*), Toon (*Cedrela toona*), Bandorhola (*Duabanga grandiflora*) etc. Moreover there are Muli bamboo (*Meloanna baccifera*), cane (*Calamus guruga*), climbers like Issarmul (*Aristolochia indica*), Jhum alu (*Dioscorea pentaphylla*) and fern, etc. in these forests. Hill forests in Bangladesh have been more severely depleted and degraded in volume, area, and quantity.

Deforestation has many significant ecological consequences including loss in biodiversity and soil quality. When a forest is lost or severely degraded, its capacity to function as regulators of the environment is also lost. Removal of forest vegetation alters soil physicochemical characteristics (Boyle 1975; Mroz et al. 1985). A number of studies reported that deforestation deteriorates soil quality through the loss of soil organic matter (Hajabbasi et al. 1997; Araujo et al. 2005), nitrogen and other nutrients (Lugoand Sanchez 1986; Araki 1992), cation exchange capacity (CEC) and exchangeable bases (Delgado et al. 1985; Ohta

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1990; Johnson et al. 1991; Saikh et al. 1998), reduction in porosity, infiltration and water holding capacity (Lu et al. 2002), increase in soil acidity, bulk density, soil erosion and runoff (Rasiah and Kay 1995) as well as loss of soil productivity (Moyo et al. 1993; Chidumayo 1989).

There are only a few reports on the deforestation and degradation of Bangladesh forests (Anonymous 1992; Hoque et al. 1997; Amin et al. 2002; Biswas and Choudhury 2007), but little information is available on the changes in soil properties due to deforestation. The objective of the present study was to assess the effects of deforestation on soil fertility in deforested hilly areas of Bangladesh.

Materials and methods

Study area

The study sites were located at Chakaria and Teknaf upazilla of Cox's Bazar district and Shitapahar of Rangamati district at Chittagong Hill Tracts (CHTs). Three natural forests and their adjacent deforested areas were included for the study. The study sites are Baraitoli (21º48'03″N–21º48'21″N; 92º04'29″E–92º04'43″E), Sitapahar (21º29'21″N–22º29'41″N; 92º10'20″E–92º10'29″E) and Jahazpura (21º1'429″N–21º1'879″N; 92º10´976″E–92º11'253″E), and the site characteristics are given in Table 1. Soils of the study sites were classified as brown hill soils (Brammer 1971). Climate in the region is tropical monsoon with mean annual temperature 25.7°C and mean annual rainfall 3,627 mm, most of which fall between May and October. The region experiences high humidity, except in the hot dry season, and winter with heavy dew and thick mist. Mean monthly relative humidity ranges between about 69% and 77% in the dry season (November to February) to about 84% and 86% in the rainy season during June to October (RSS 1976).

Table 1. Site characteristics of forested and deforested lands

Site		Altitude (m)	Position	Aspect	Slope (%)	Vegetation
Baraitoli	Forested	15	Lower slope	NW	12-25	Garjan, Jam
	Deforested	6	Lower slope	NW	30	herbs Shrubs
Sitapahar	Forested	49	crest	Hilltop	65	Mixed forest
	Deforested	45	crest	Hilltop	65	Barren
Jahazpura	Forested	4	Flat	hilltop	2	Garjan
	Deforested	4	Flat	hilltop	2	Barren

In Baraitoli of Chakaria, the dominant tree species are Garjan (*Dipterocarpus spp.*), and Jam (*Syzygium spp.*). In natural forest of Sitapahar at Rangamati, the vegetation is composed of Urium *(Mangifera sylyatica)*, Kanak (*Schima wallichii*), Bhadi (*Lannea grandis*), Gab (*Diospyros peregrina*), Garjan (*Dipterocarpus spp.),* Chhatim (*Alstonia scholaris*), Jam (*Syzygium spp.),* Batna (*Quercus spp*.) and some other minor tree species. In the natural forest of Jahazpura at Teknaf, the dominant tree species are Garjan (*Dipterocarpus spp.*), but this forest also contains a few other tree species like Telsur (*Hopea odorata*), Gutgutiya (*Protium serratum*), Chapalish (*Artocarpus chaplasha*), Boilam (*Anisoptera scaphula)*, Urium*(Mangifera sylyatica)*, Jarul (*Legarstromia speciosa*), Hargoza (*Dillenia pentagyna*), Horitoki (*Terminalia chebula*), Bohera (*Terminalia bellerica*), Hizol (*Barringtonia acutangula*) etc.

Soil sample and measurement

Soil profiles were dug in each site and soil samples were collected from 18 profiles (three natural forest sites, three deforested sites, three profiles from each site) for analysis. Soil samples were taken from three successive horizons of each profile at the depths of 0–15 cm (top), 15–55 cm (middle) and 55–85 cm (bottom). Soil samples were air-dried, and passed through 2.0 mm sieve.

Particle size distribution of the soils was determined by hydrometer method (Day 1965). Bulk density of soils was determined by core method as described by Blake (1965). Cation exchange capacity (CEC) was determined after extraction with 1 N ammonium acetate solution (Black 1965). Soil pH was measured in soil-water suspension (1:2.5) using a corning glass electrode. Organic carbon, organic matter and total nitrogen were determined by wet-oxidation method of Walkley and Black (1934) and micro-Kjeldahl method (Jackson 1973), respectively. Exchangeable calcium and magnesium were determined by EDTA method, and potassium and sodium were determined using a flame photometer (Jackson 1973). Available phosphorus was extracted with Bray and Kurtz no.2 extractant and measured by $SnCl_2$ reduced molybdophosphoric blue color method using spectrophotometer (Jackson 1973). Significance of difference in soil properties between forested and deforested sites was tested by paired t test using Minitab (1996).

Results and discussion

Soil physical characteristics

Particle size of the soils was dominated by sand and did not significantly differ between forested and deforested sites (Table 2). Brammer (1971) reported that sand is the dominant particle in brown hill soils because they developed from sandstone parent materials. However, subsoils were to some extent finer. Clay migration has occurred in subsoil due to coarser texture and higher internal drainage. The deep and extensive root system of forest trees leaves huge macro and micro pores in the soil body to a greater depth. This could encourage clay migration throughout forest soil profile. During profile excavation, porosity was noticed to be in the higher range in the natural forest soil in comparison to that of the deforested barren site. This was in conformity with works of other investigators (Sahani and Behera 2001; Hajabbasi et al. 1997).

The bulk density of soils varied from 1.21 $Mg{\cdot}m^{-3}$ at top soil in forested site to 1.58 $Mg{\cdot}m^{-3}$ at bottom soil in deforested site (Table 2). The soils of surface and middle layers in forested sites had significantly lower bulk density than deforested sites. Low

organic matter content caused a higher bulk density for the soils of the deforested sites. The high soil bulk density also indicated soil compaction due to deforestation. This would ultimately lead to a reduction in soil porosity and a decrease in permeability (Agboola 1994). Hajabbasi et al. (1997) and Liu et al. (2002) also observed higher bulk density in deforested soil. Hajabbasi et al. (1997) suggested that higher bulk density of the deforested sites could result in a lower soil quality.

Table 2. Soil particle size distribution and bulk density between the forested and deforested areas

Soil depth	Land use	Particle size distribution (%) Sand	Silt	Clay	Bulk density ($Mg\cdot m^{-3}$)
Top	Forest	$78^a\pm0.36$	$8^a\pm3.48$	$14^a\pm6.91$	$1.22^a\pm0.0666$
	Deforest	$78^a\pm2.43$	$10^a\pm3.36$	$12^a\pm9.28$	$1.37^b\pm0.0306$
Middle	Forest	$70^a\pm23.4$	$10^a\pm5.81$	$20^a\pm18.0$	$1.21^a\pm0.1323$
	Deforest	$75^a\pm15.0$	$8^a\pm3.25$	$17^a\pm12.4$	$1.46^b\pm0.0802$
Bottom	Forest	$65^a\pm21.4$	$12^a\pm9.59$	$23^a\pm15.05$	$1.36^a\pm0.060$
	Deforest	$76^a\pm13.7$	$7^a\pm2.54$	$17^a\pm12.11$	$1.58^a\pm0.369$
Grand mean		$71^a\pm76.46$	$10^a\pm8.05$	$19^a\pm15.52$	

Each value is the mean of three replicates. The same letter within each soil depth indicates no significant difference ($p<0.05$)

Soil chemical characteristics

Soil pH ranged from 3.99 to 4.52 in the soils of the forested sites and 3.62 to 3.98 in the deforested sites (Table 3). Soil pH at all sites decreased with depth. The pH values at top soils and bottom soils of the forested areas were significantly higher in comparison to the deforested sites. Deforestation may have encouraged removal of bases by run-off and leaching. Forest vegetation also circulates bases within the soil profile during nutrient recycling. Deciduous and evergreen forest soils are somewhat richer in Ca^{2+} (Saikh et al. 1998). On the contrary, intensive leaching of bases in barren land enhances reduction in soil pH.

Table 3. Changes of soil chemical properties between the forested and deforested areas

Soil depth	Land use	pH (H_2O)	Organic matter(%)	Total N (%)	Available P($mg\cdot kg^{-1}$)
Top	Forest	$4.52^a\pm0.615$	$1.24^a\pm0.197$	$0.14^a\pm0.0200$	$4.38^a\pm5.15$
	Deforest	$3.98^b\pm0.410$	$0.77^b\pm0.205$	$0.10^b\pm0.0153$	$4.91^a\pm6.11$
Middle	Forest	$4.15^a\pm0.605$	$0.61^a\pm0.262$	$0.08^a\pm0.0231$	$3.22^a\pm3.37$
	Deforest	$3.64^a\pm0.517$	$0.34^a\pm0.099$	$0.06^a\pm0.0200$	$1.95^b\pm3.18$
Bottom	Forest	$3.99^a\pm0.419$	$0.25^a\pm0.0929$	$0.06^a\pm0.0306$	$2.59^a\pm3.73$
	Deforest	$3.62^b\pm0.505$	$0.13^a\pm0.0153$	$0.04^a\pm0.0208$	$0.59^a\pm0.50$

Each value is the mean of three replicates. The same letter within each soil depth indicates no significant difference ($p<0.05$)

The surface soil at all sites had the greatest amount of organic matter. Surface soils in the forested sites contained significantly higher amount of organic matter (1.24%) compared to the deforested sites (0.77%). A number of studies have shown that tropical deforestation lowers soil organic matter (Lugo and Sanchez 1986). Organic matter content of lower layers (middle and bottom depths) did not show any significant difference. Similar results were reported by Hajabbasi et al. (1997). Greater decomposition and removal by erosion might be causes of lower organic matter in the deforested soils.

The surface soil of deforested sites showed significantly lower amount of total nitrogen. The highest content of total nitrogen was observed in forested top soils. Patrick and Smith (1975) reported that total tree harvesting caused the loss of nutrients including nitrogen up to three times compared to conventional lodging. In addition to losses from biomass removal, nutrients can be lost from deforested areas by higher soil nutrient mobilization and leaching, when little vegetation is present to take up (Mroz et al. 1985).

In the surface soil, available phosphorus content was lower in the forested soils than that of deforested soils although their difference was not significant. However, in soils of middle portion, available phosphorus contents were significantly higher in forested than deforested soils. Similar observation was reported by Hajabbasi et al. (1997). The available phosphorus content showed a decreasing trend with depth in the forested and deforested sites. Similar results were also found in some soils of Chittagong hill tracts by Chowdhury (2007).

Exchangeable bases and cation exchange capacity

The contents of exchangeable cations and cation exchange capacity (CEC) are presented in Table 4. Exchangeable Ca^{2+} and K^+ were significantly higher in surface and subsurface soil of the forested sites. Exchangeable Mg^{2+} was higher in all depths of forested areas. On the other hand, exchangeable Na^+ was not significantly different in any depth of soil. Thus deforestation has considerably removed exchangeable bases of the soil. This could be due to higher organic matter content in the forested soil and higher leaching in the deforested soil. Similar trends of variation in exchangeable cations were reported by Adama and Boyle (1982) and Saikh et al. (1998). However, CEC was not significantly different between soils of the forested and deforested sites and followed a similar trend of decrease with the depths. Forested soils, however, contained higher level of CEC at all depths than deforested areas. Allen (1985) observed that reduction in CEC was 50% higher in the tropical soils than in temperate soils under deforestation. Adejuwon and Ekanade (1987) also reported the losses of 34%–36% in CEC and 19%–50% in exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+ in the tropical region due to deforestation.

Conclusion

The impact of deforestation on some physical and chemical characteristics of hill forest in Cox's Bazar and Rangamati districts of Bangladesh was assessed. Deforestation has significantly deteriorated soil quality by increasing bulk density and decreasing soil pH, available phosphorus, exchangeable bases like Ca^{2+}, Mg^{2+} and K. This deterioration would further affect the utilization of these soils for future reforestation. Reforestation and

regular protection may be the best possible way to restore soil productivity in the deforested sites.

Table 4. Changes of soil exchangeable bases and cation exchange capacity (CEC) between the forested and deforested areas

Soil depth	Land use	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC
		$cmolc \cdot kg^{-1}$				$cmolc \cdot kg^{-1}$
Top	Forest	$2.47^a \pm 1.180$	$1.15^a \pm 0.552$	$0.37^a \pm 0.0800$	$0.06^a \pm 0.0306$	$11.85^a \pm 0.57$
	Deforest	$1.89^b \pm 1.081$	$0.89^b \pm 0.566$	$0.33^b \pm 0.0755$	$0.08^a \pm 0.0321$	$9.07^a \pm 3.10$
Middle	Forest	$1.51^a \pm 0.898$	$0.70^a \pm 0.203$	$0.23^a \pm 0.01528$	$0.07^a \pm 0.0289$	$10.31^a \pm 2.22$
	Deforest	$1.04^b \pm 0.719$	$0.43^b \pm 0.272$	$0.15^b \pm 0.01528$	$0.05^a \pm 0.0300$	$8.59^a \pm 2.64$
Bottom	Forest	$1.04^a \pm 0.504$	$0.48^a \pm 0.176$	$0.20^a \pm 0.0058$	$0.07^a \pm 0.0321$	$9.68^a \pm 1.72$
	Deforest	$0.65^a \pm 0.280$	$0.29^b \pm 0.168$	$0.16^a \pm 0.0458$	$0.04^a \pm 0.0153$	$8.48^a \pm 3.11$

Each value is the mean of three replicates. The same letter within each soil depth indicates no significant difference ($p<0.05$)

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